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NASA CASE NO. MSC-18,407-1

PRINT FIG. 1

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(NASA-Case-MSC-18407-1) DIRECT CURRENT
BALLAST CIRCUIT FOR METAL HALIDE LAMP
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DIRECT CURRENT BALLAST CIRCUIT FOR METAL HALIDE LAMP

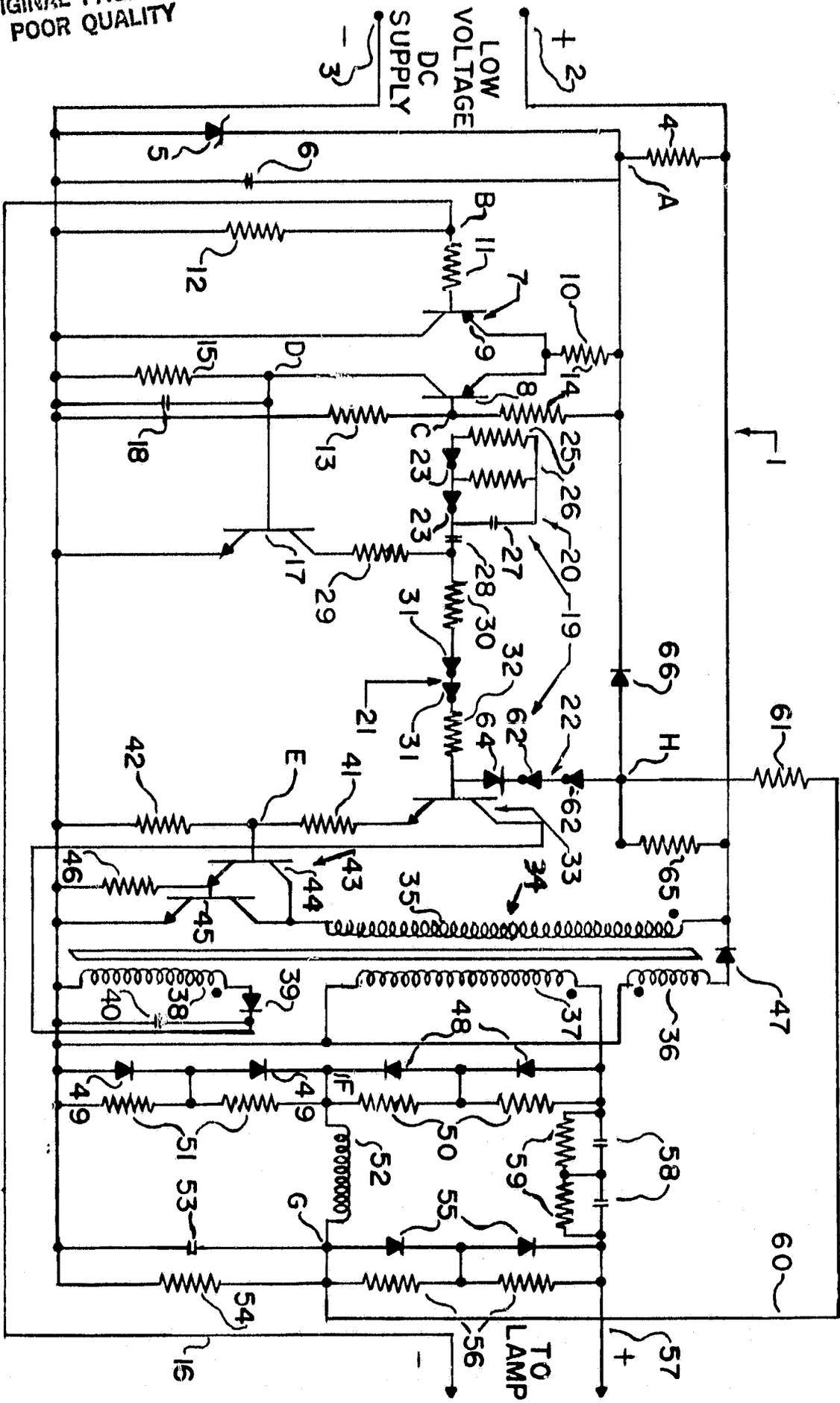
The invention relates in general to ballast and starting circuitry for operating gaseous discharge lamps from direct current, and more particularly to such circuitry with a current regulated output characteristic for operating metal halide lamps wherein a high frequency switching means is alternately switched between on and off conductive states. Metal halide light sources have been chosen for the space shuttle payload bay because of their high luminous efficiency, good color rendition, and long life.

The invention comprises a direct current ballast circuit (1) for a two electrode metal halide lamp. The ballast circuit (1) is connected to a low voltage DC input (2,3) and includes a high frequency circuit comprising a square wave oscillator, amplifier and squaring circuit (19), a high frequency power amplifier (43) and transformer (34) for developing a high voltage output. Duty cycle of the circuit is controlled by transistor (17). The output voltage is rectified by diodes (48, 49) and filtered by inductor (52) and capacitor (53) to provide a current regulated DC output through commutating diodes (55) for controlling the metal halide lamp. An alternating current path is provided in the output winding (37) of the transformer (34) in parallel with the rectifiers (48, 49) and filter (52, 53) for providing a starting voltage to the metal halide lamp. A feedback path is provided from the output of the filter capacitor (53) through a bias resistor (61) to power the high frequency circuit which includes the power amplifier (43) and transformer (34) and thereby sustain circuit operation during any low voltage transients which may appear on the input DC supply (2, 3). A current sensor (12) is connected to the output of the lamp for regulating the switching duty cycle of the power amplifier (43) following breakdown of the lamp element.

The 20 kilohertz inverter provides excellent power conversion efficiency in addition to an automatic shut down and restart capability. The circuit is current regulated by a fast response lamp current control loop. Further, the circuit automatically corrects for magnetic imbalances in the transformer by returning excess energy to the power supply thereby improving conversion efficiency.

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DIRECT CURRENT BALLAST CIRCUIT FOR METAL HALIDE LAMP
ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject
5 to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; U.S.C. 2457).

TECHNICAL FIELD

My invention relates in general to ballast and
10 starting circuitry for operating gaseous discharge lamps from direct current, and more particularly to such circuitry with a current regulated output characteristic for operating metal halide lamps wherein a high frequency switching means is alternatively switched between on and
15 off conductive states.

Metal halide light sources have been chosen for the space shuttle payload bay. This light source is advantageous because it has high luminous efficiency, good color rendition, and long life. A 28 volt DC power source
20 is provided for the driving circuitry. However, rather than several ballast size and weight limitations are present.

The foregoing requirements suggest the use of 20 kilohertz inverter technology, which has been shown to provide excellent power conversion efficiency in packages
25 of low weight and volume. In addition, it was expected that some of the concepts that have been developed for fluorescent lighting could be applied to this task.

Fluorescent lamps perform well when operated on
20 kilohertz AC power. Attempts to apply power of this
30 type to metal halide lamps, however, resulted in objectionable flicker, erratic power level and color, and unpredictable arc blowouts. It was found that the difficulties appear at frequencies above 1 kilohertz, increasing in severity as the frequency is raised. It
35 was further found that the inclusion of a reactive ballast element, i.e., an inductor, a capacitor or both, made the instability worse.

For the above reasons, it was concluded that those circuit characteristics that are most advantageous from an electronic standpoint for fluorescent lamps, result in the poorest lamp behavior for metal halide lamps.

BACKGROUND ART

U.S. Patent 4,132,295 discloses a direct current ballasting and starting circuitry for gaseous discharge lamps which employs a series-pass switching transistor in one of a pair of input lines. The current conducted by the switching transistor is limited by connecting current sensing means in series with the switching transistor. Filtering means are provided in series with the current sensing means for smoothing pulses of energy delivered by the switching means for the DC voltage source. The filtering means provides a direct current output with a comparatively small alternating current component thereon.

Starting circuitry is included in series connection between the filter means and an output terminal of the circuitry for sensing the non-ionized condition of a lamp connected to the output terminal. The starting circuitry further provides a voltage pulse of sufficient magnitude and duration to initiate ionization within the lamp. Once ionization is achieved, the starting circuitry becomes inactive and does not impede the supply of direct current from the filter means to the lamp.

DISCLOSURE OF THE INVENTION

In accordance with the present invention, I provide a direct current ballast circuit for a two electrode metal halide lamp. The direct current ballast circuit is connected to a low voltage DC input and includes a high frequency circuit including a high frequency power amplifier and transformer for developing a high voltage output. The output voltage is rectified by DC rectifiers and filtered to provide a current regulated DC output for controlling the metal halide lamp. An alternating path is provided in the output winding of

the transformer in parallel with the DC rectifiers and filter for providing a starting voltage to the metal halide lamp. A feedback path is provided from the output of the filter through a bias resistor to power the high frequency
5 circuit which includes the power amplifier and transformer and thereby sustain circuit operation during low voltage transients on the input DC supply. A current sensor is connected to the output of the lamp for regulating the switching duty cycle of the power amplifier following
10 breakdown of the lamp element.

BRIEF DESCRIPTION OF THE DRAWING

The details of my invention will be described in connection with the accompanying drawing, in which Figure 1 is a circuit schematic of the preferred embodiment of
15 the DC ballast circuit.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to Figure 1, there is shown a DC to DC power conversion circuit 1 provided for controlling a metal halide lamp. As illustrated the power conversion
20 circuit 1 includes a positive input terminal 2 and a negative input terminal 3 coupled to a low voltage DC supply. A resistor 4 is connected to the positive input terminal 2 and to a node A in series with a Zener diode 5 which is connected between the node A and the negative
25 input terminal 3. The resistor 4 provides a bias voltage which causes the Zener diode 5 to generate a reference voltage at the node A. A capacitor 6 is connected in parallel with the Zener diode 5 to provide stability for the reference voltage at node A.

30 A comparator 7 is provided including transistors 8 and 9. The emitters of the transistors 8 and 9 of the comparator 7 are coupled to the reference voltage at node A through a bias resistor 10. The reference voltage at node A provides a bias voltage for
35 the comparator 7. The base of transistor 9 of the comparator 7 is biased through a resistor 11. The resistor 11 is connected at a node B to a resistor 12

coupled to the negative input terminal 3. Resistors 13 and 14 form a voltage divider at node C between node A and the negative input terminal 3. This provides a bias voltage at node C for the base of transistor 8 of the
5 comparator 7. The collector of transistor 9 of the comparator 7 is tied directly to the negative input terminal 3. The collector of transistor 8 of the comparator 7 is connected to the negative input terminal 3 through a resistor 15 at a node D. A feedback line 16
10 is coupled from the negative terminal of the lamp to the node B. During startup before lamp breakdown, with no current flowing through the feedback line 16, the base of transistor 9 of the comparator 7 is biased much more negative than the base of transistor 8. This drives the
15 transistor 9 of the comparator 7 into saturation. As a result the entire reference voltage generated by the Zener diode 5 is dropped across bias resistor 10 and no current flows in the base and collector circuits of the transistor 8.

20 A transistor 17 having its base coupled to the collector of transistor 8 of the comparator 7 is controlled by the comparator. A low path filter capacitor 18 is connected from the base of the transistor 17 to the negative input terminal 3. The capacitor 18 cuts off high
25 frequency responses from the comparator 7. A hex inverter 19 is provided having three amplifier circuits 20, 21 and 22. The amplifier circuit 20 of the hex inverter 19 includes inverters 23, resistors 25 and 26 and a capacitor 27 which are all electrically coupled to form a square
30 wave oscillator. The amplifier circuit 20 is coupled to the collector of the transistor 17 through a capacitor 28 and a bias resistor 29. A resistor 30 is coupled to the capacitor 28 to form a differentiator and current source. The square wave signal provided by the amplifier circuit
35 20 is the waveform standard for the conversion circuit 1.

The amplifier circuit 21 of the hex inverter 19 includes serially coupled inverters 31. The amplifier

circuit 21 is coupled to the amplifier circuit 19 through the resistor 30 and capacitor 28. The amplifier circuit 21 is also coupled to the base of a switching transistor 33 through a current limiting resistor 32. The amplifier
5 circuit 21 speeds up and squares the signal generated by the amplifier circuit 20.

A power transformer 34 is provided having a primary winding 35 and secondary windings 36, 37 and 38. A supply voltage formed of secondary winding 38 of the
10 power transformer 34, diode 39 and capacitor 40 is provided to the collector of switching transistor 33. The emitter of the switching transistor 33 is coupled to the negative input terminal 3 through resistors 41 and 42. The switching transistor 33 provides drive to a Darlington
15 power amplifier 43.

The power amplifier 43 formed of transistors 44 and 45 is provided to drive the power transformer 34. The base of the transistor 44 of the power amplifier 43 is coupled at a node E to the negative input terminal 3
20 through resistor 42. Base drive for the transistor 44 of power amplifier 43 is provided by switching transistor 33 through resistor 41. The resistor 42 assures that the transistor 44 of the power amplifier 43 is off when switching transistor 33 is off. The primary winding 35
25 of the power transformer 34 is connected to the collectors of the transistors 44 and 45 of the power amplifier 43 and to the positive input terminal 2.

The emitter of the transistor 44 of the power amplifier 43 is coupled to the base of transistor 45 of
30 the power amplifier and then to the negative input terminal 3 through resistor 46. The resistor 46 assures that transistor 45 of the power amplifier 43 is off when transistor 44 of the power amplifier is off. The emitter of the transistor 45 of the power amplifier 43 is coupled
35 directly to the negative input terminal 3. The transistor 17 which is controlled by the comparator 7 controls the duty cycle of the power amplifier 43 through

its control of the amplifier circuits 20 and 21 of the hex inverter 19. When the transistor 17 is turned off the duty cycle of the power amplifier 43 driving signal approaches 50% whereas when transistor 17 is conducting
5 the duty cycle of the driving signal decreases.

The power amplifier 43 drives the power transformer 34. That is, the switching of current by the power amplifier 43 through primary winding 35 of the power transformer 34 induces voltages in the secondary windings
10 36, 37 and 38 of the power transformer.

The secondary winding 36 of the power transformer 34 is connected in parallel to the positive and negative input terminals 2 and 3. The secondary winding 36 of the power transformer 34 automatically
15 corrects for magnetic imbalances in the transformer by returning excess energy not used by the lamp to the power supply through a diode 47. This helps improve the efficiency of the conversion circuit 1. Rectifying diodes 48 and 49 are connected between the secondary
20 winding 37 of the power transformer 34 and a node F. Resistors 50 and 51 are connected in parallel to the diodes 48 and 49, respectively. The diodes 48 and resistors 50 provide a rectified output at the node F to charge an inductor 52. The diodes 49 and resistors 51
25 provide a discharge path for the inductor 52 as the inductor's magnetic field declines. The inductor 52 is connected at a node G to a filter capacitor 53 and a resistor 54 which are connected to the negative input terminal 3. The inductor 52 and filter capacitor 53 store
30 DC energy from the rectifying diodes 48 and 49. Commutating diodes 55 and resistors 56 are coupled between the node G and an output terminal 57 of the conversion circuit 1. The commutating diodes 55 and resistors 56 block the alternating current component induced in the
35 secondary winding 37 of the power transformer 34 to aid in lamp startup. Capacitors 58 and resistors 59 are coupled between the secondary winding 37 of the power transformer

34 and the output terminal 57. Capacitors 58 and resistors 59 provide a conduction path for the alternating current waveform induced in the secondary winding 37 of the power transformer 34 to aid lamp startup.

5 Additionally, the commutating diodes 55, resistors 56, capacitors 58 and resistors 59 develop a peak voltage at the frequency of the power amplifier 43 during startup to take advantage of capacitor effects within the lamp to aid lamp breakdown.

10 A feedback loop 60 is provided including a resistor 61 coupled to the amplifier circuit 22 of the hex inverter 19 at a node H. The amplifier circuit 22 of the hex inverter 19 includes serially connected inverters 62. The amplifier circuit 22 is coupled to the base of the
15 switching transistor 33 through a diode 64. The amplifier circuit 22 provides signal amplification and limiting through the diode 64. As a result when a relatively slow short circuit is transmitted from the node G by the resistor 61, the diode 64 will establish a conduction path
20 from the amplifier circuit 22 to the switching transistor 33. This will shut down the conversion circuit 1. When there is no short circuit transmitted by the resistor 61, the diode 64 isolates the amplifier circuit 22 from the switching transistor 33 to prevent the conversion circuit
25 1 from shutting down. Accordingly, the conversion circuit 1 has an automatic shut down and restart feature.

A resistor 65 is coupled from the positive input terminal 2 to a diode 66 at the node H. The diode 66 is coupled from the node H to the node A. The resistor 65 and
30 diode 66 prevent the voltage on the hex inverter 19 from exceeding a safe level.

As the lamp breaks down, the voltage at node 57 falls and energy is transferred from the filter capacitor 53 to the lamp and into line 16. Resistor 12 senses the
35 lamp conduction and builds voltage at node B. The voltage at node B reduces the conduction of transistor 9 of the comparator 7 and correspondingly increases conduction

through transistor 8 of the comparator.

The current flow through the collector circuit of the transistor 8 of the comparator 7 builds a voltage at node D through resistor 15 and tends to reduce the base drive for the switching transistor 33 and thereby limit the switching of the amplifier 43. This stabilizes the current flow through the lamp.

Lamp stability is maintained without a ballast element through use of the described fast response lamp current control loop. This speed of response is essential to successful operation. For example, the output filter capacitor 53 must be carefully chosen. If large values are used, starting impulse energy is increased and electro-magnetic interference from the residual transformer ripple is reduced. But circuit response time may be reduced to the point at which the lamp will oscillate or extinguish.

It will be understood that various changes and modifications can be made without departing from the spirit of the invention as defined in the following claims.

ABSTRACT OF THE DISCLOSURE

The object of this invention is to provide a direct current ballast circuit (1) for a two electrode metal halide lamp. Said direct current ballast circuit
5 (1) includes a low voltage DC input and a high frequency power amplifier (43) and power transformer (34) for developing a high voltage output. The output voltage is rectified by diodes (48) and (49) and filtered by inductor (52) and capacitor (58) to provide a regulated
10 DC output through commutating diodes (55) to one terminal of the lamp at the output terminal (57).

Another object is to provide a feedback path from the output of the filter capacitor (53) through the bias resistor (61) to power the high frequency circuit
15 which includes the power amplifier (43) and the power transformer (34) for sustaining circuit operations during low voltage transients on the input DC supply.

Another object is to provide a current sensor (12) connected to the output of the lamp through terminal
20 (16) for stabilizing lamp current following breakdown of the lamp.

